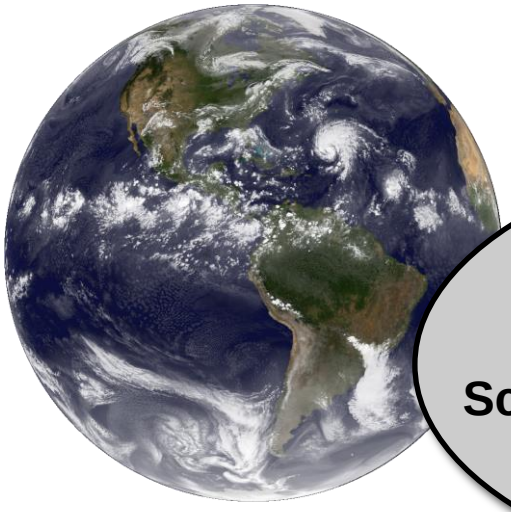
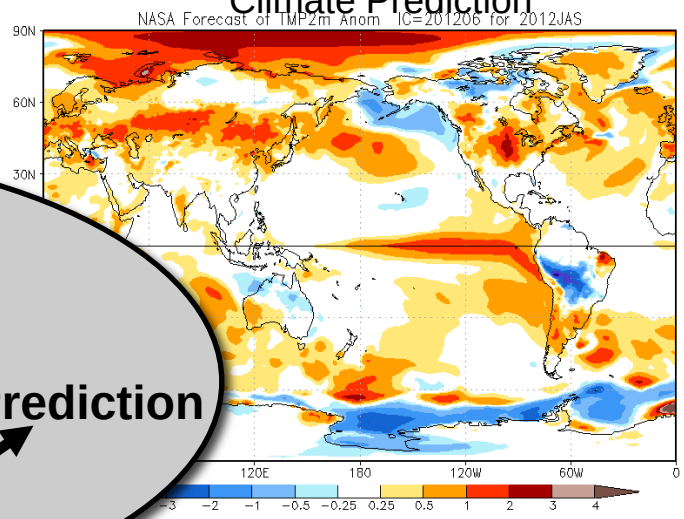
Global Climate & Weather Modeling and Satellite Data Assimilation in the GMAO

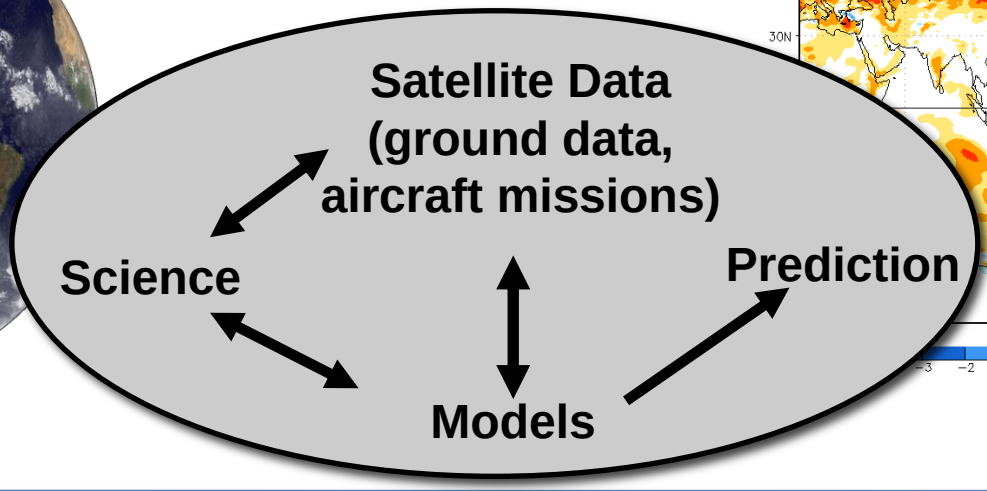
Steven Pawson, Michele Rienecker
Global Modeling and Assimilation Office

Weather Prediction



Climate Prediction





Global Modeling of the Earth System at NASA

Analysis and Weather Prediction

Seasonal to Interannual Climate Prediction

Decadal to Multidecadal Scale Climate Change

Paleoclimate

Driven by initial conditions

Driven by boundary conditions

Hours Days Weeks Season Year Decades Centuries Millennia

High resolution
<1 -10km

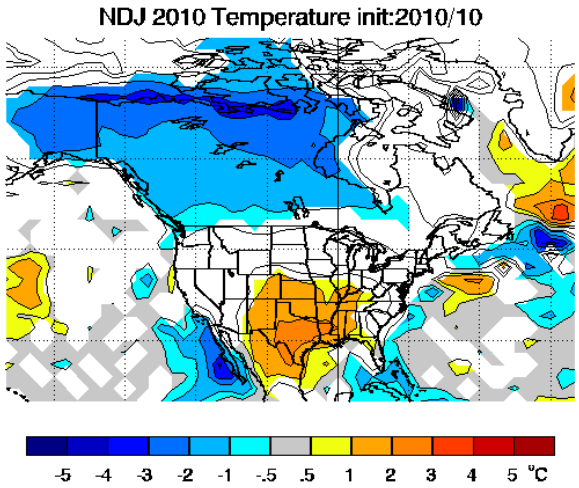
Medium resolution
50-100km

Coarse resolution
200 - 500km

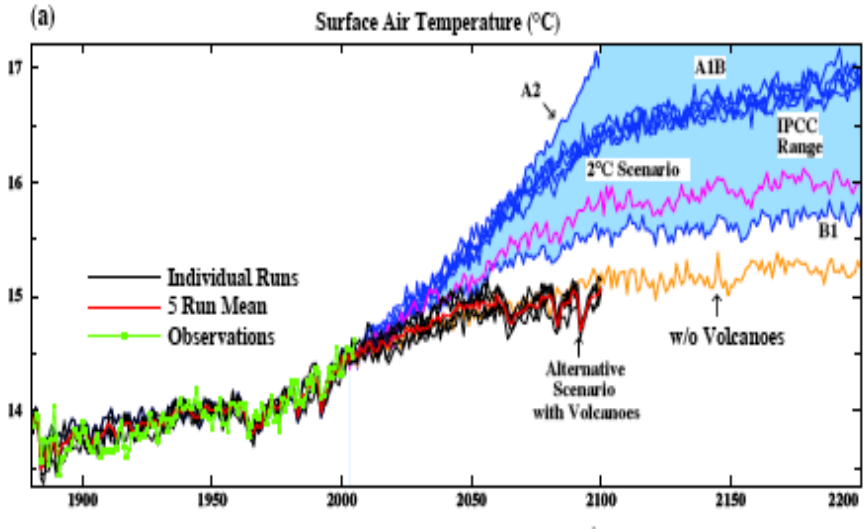
GEOS-5

GISS Model E

NASA modeling spans spatial scales from kilometers to global and time scales from minutes to millenia.

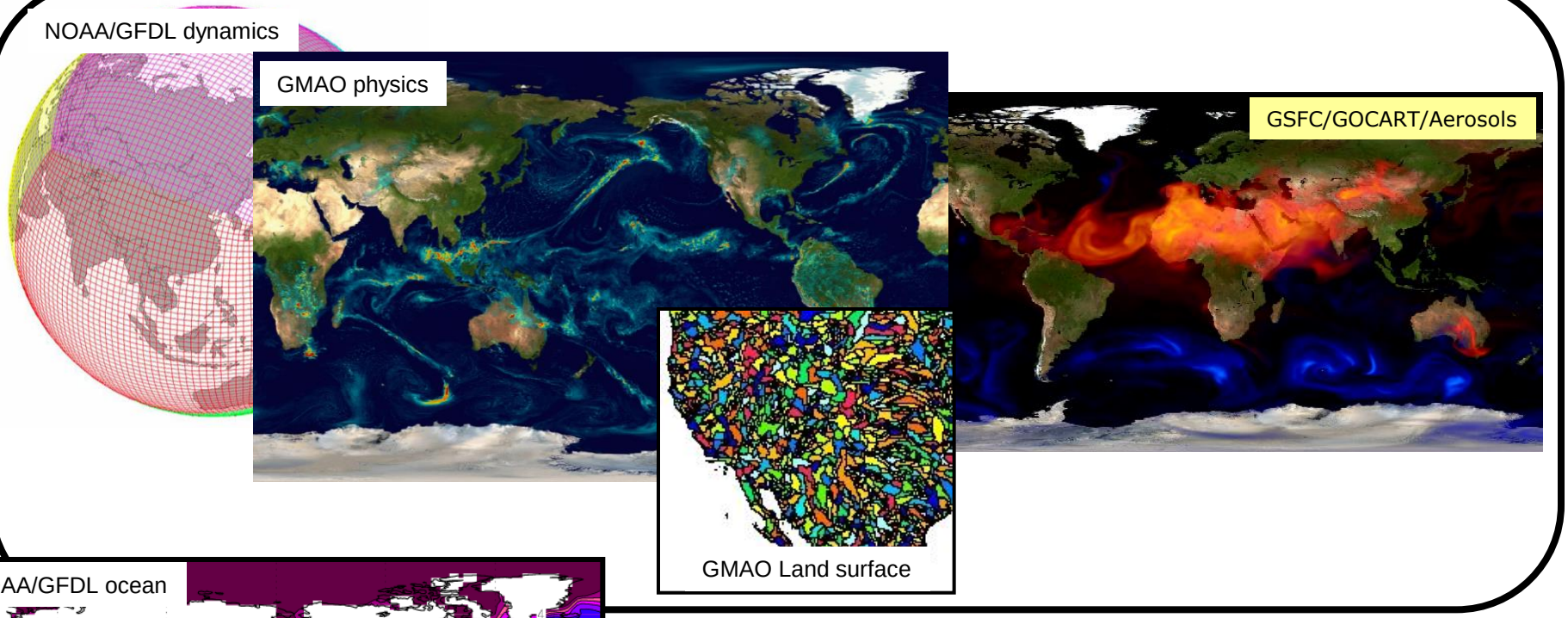


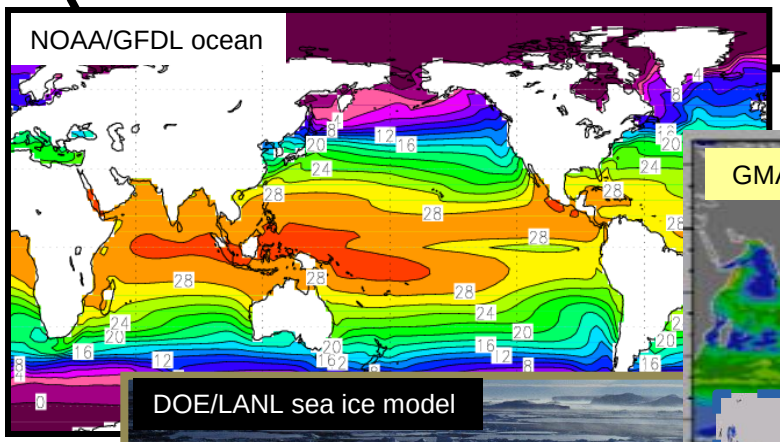
GEOS 5 November, December, January 2010-11 Forecast Temperature Anomalies, from October 2010 Initial Conditions

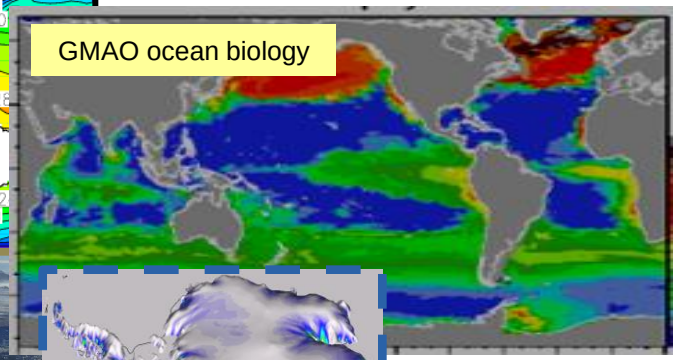


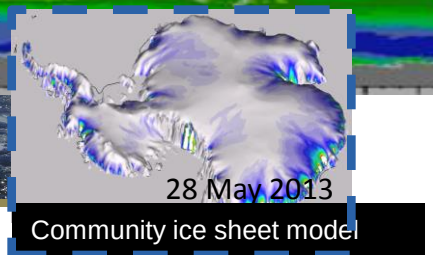
GISS Model E Global Mean Surface Air Temperature Forecasts through 2200

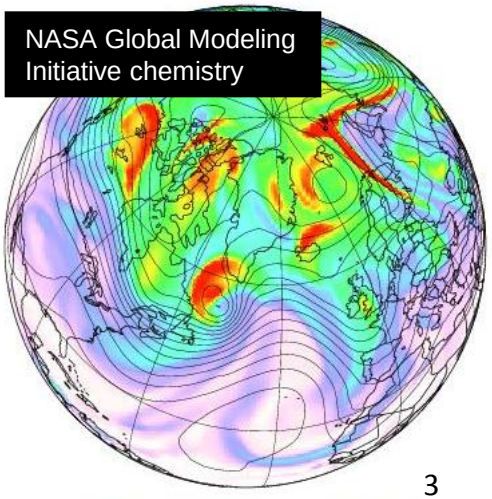
GEOS Model – Integration of components from a variety of sources







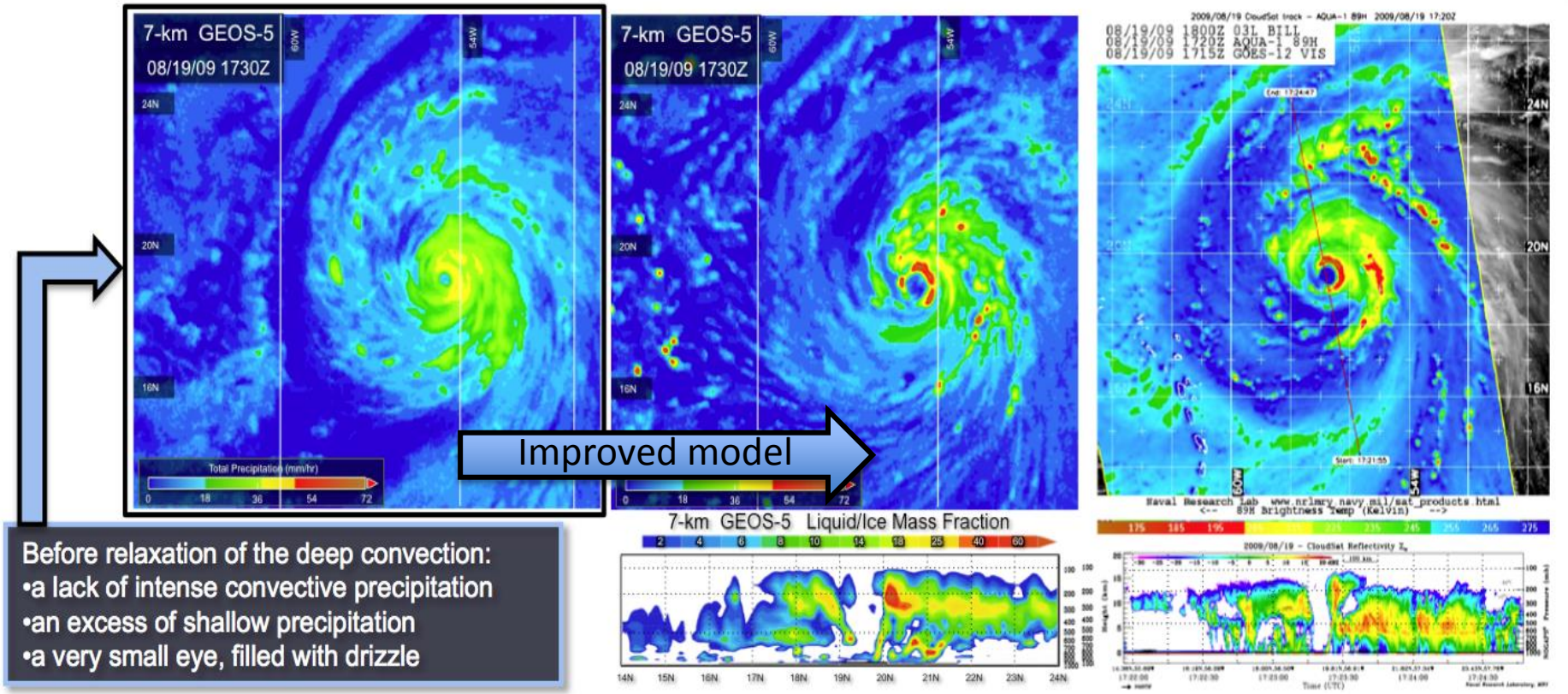




NASA's GEOS modeling: "data-driven"

- Data assimilation – products for weather and climate applications
- Model – data comparisons to guide model developments

GEOS-5 Simulations of 2009 Atlantic Hurricane Bill: Impacts of Model Formulation



Before relaxation of the deep convection:
- a lack of intense convective precipitation
- an excess of shallow precipitation
- a very small eye, filled with drizzle

GEOS-5

Multi-Scale Modeling Approach

Seamless prediction in a unified model development framework

A comprehensive global model suitable for:
simulation – assimilation – weather – climate

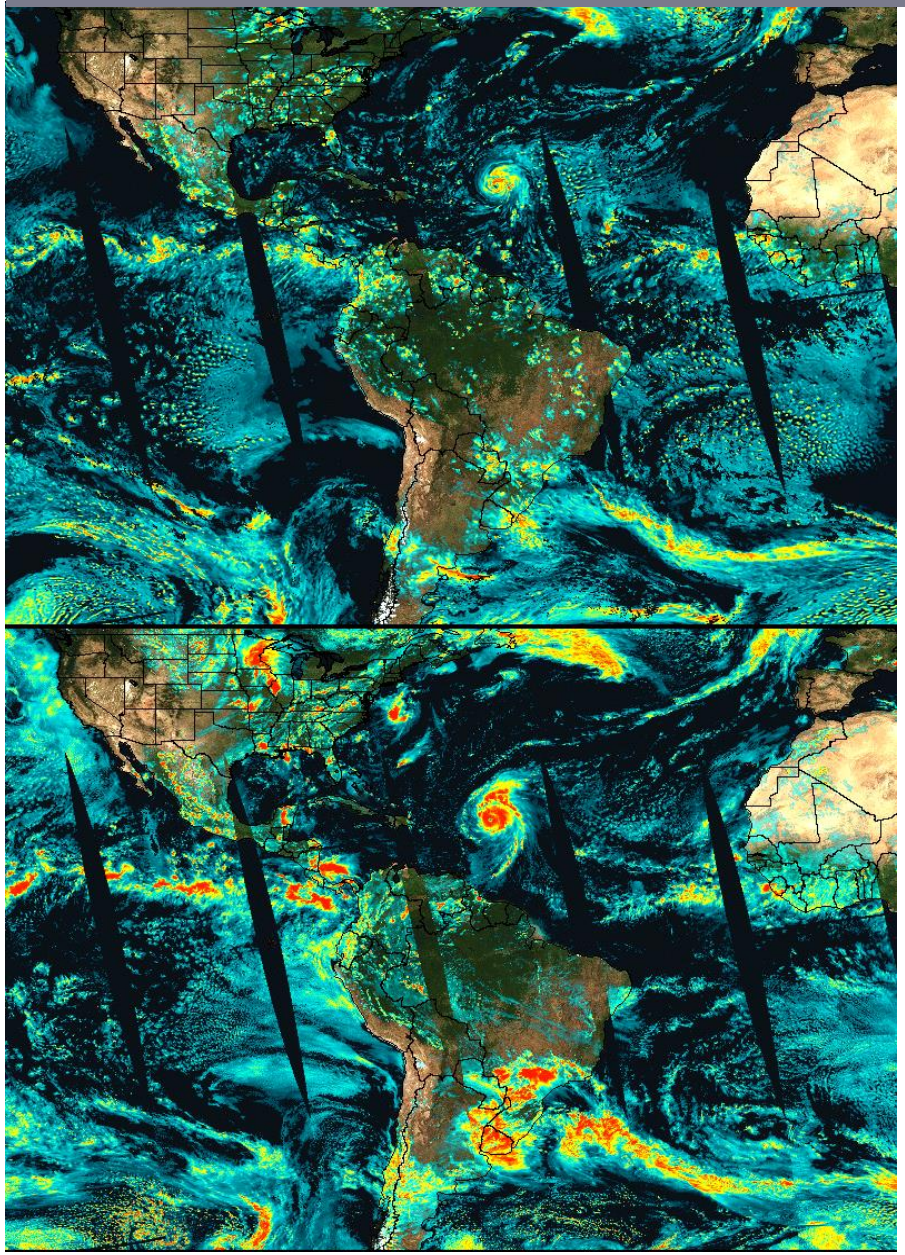
Various resolutions:
1-deg (climate) ¼-deg (weather) 10- to 3.5-km (mesoscale)

Hydrostatic and non-hydrostatic

Resolution-dependent physics parameterizations:
- Moist processes and aerosol-cloud interactions
- Cloud and deep convective parameterization
- Non-precipitating shallow convection
- Gravity wave drag

Within a single codebase and a single build

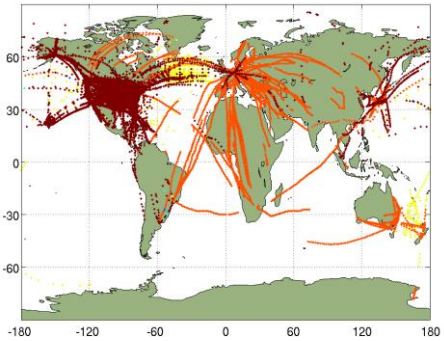
7-km GEOS-5 Cloud Optical Thickness



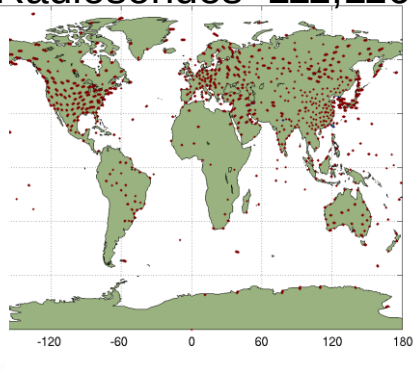
MODIS Cloud Optical Thickness

GMAO's Atmospheric Data Assimilation

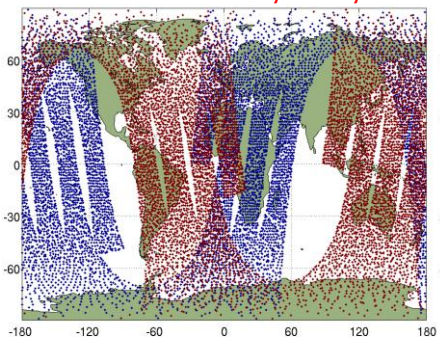
Aircraft 166,109



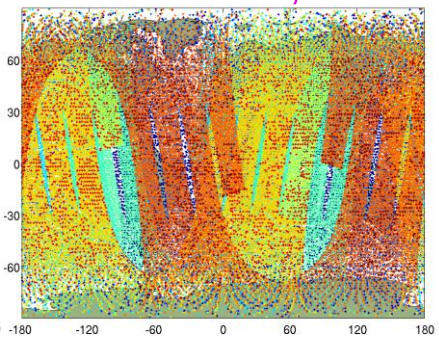
Radiosondes 111,116



AIRS/IASI 1,211,660

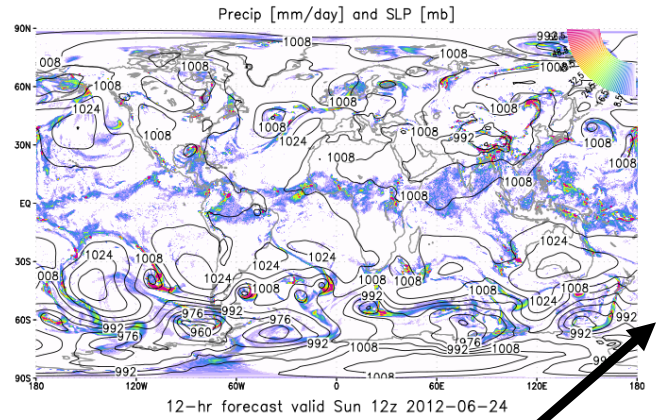


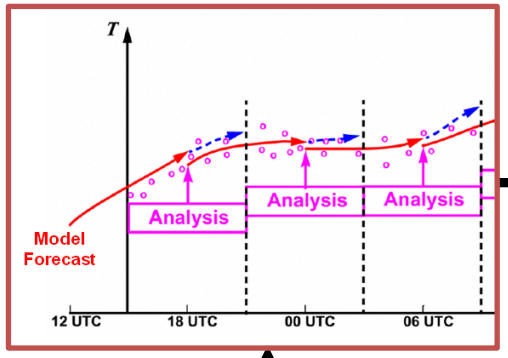
ATOVS 670,532

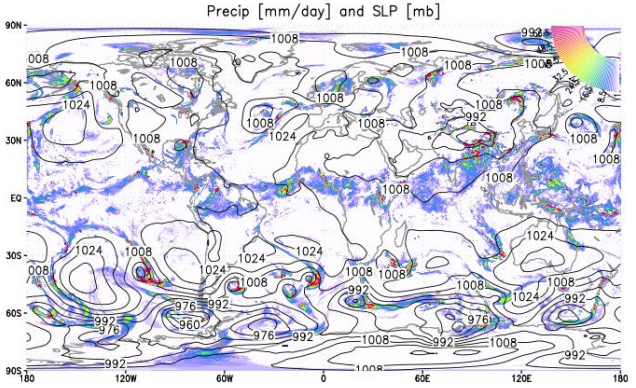


Temperature, moisture, wind profiles from Radiosondes, Aircraft, Profilers

Operational and Research Satellite Sounders

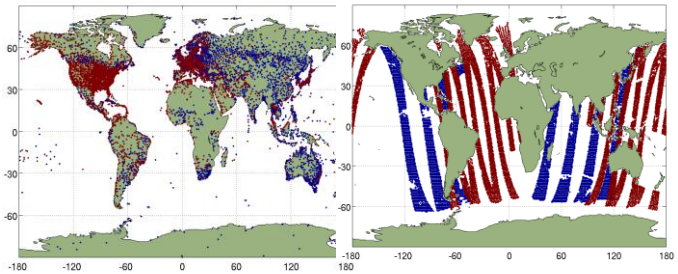






Model Forecast provides the first guess for the analysis

Surface Observations



Analyses of the atmospheric state for climate analysis and initialization of predictions

Hurricane Sandy

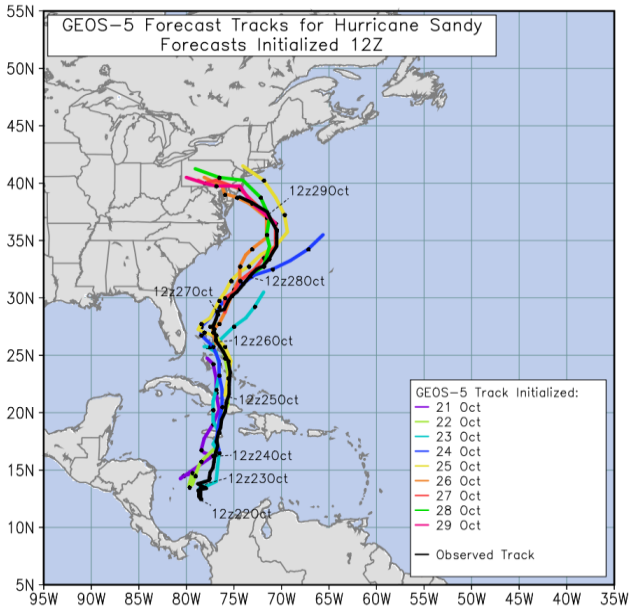
Accurate 5-day Track Forecasts from GEOS-5

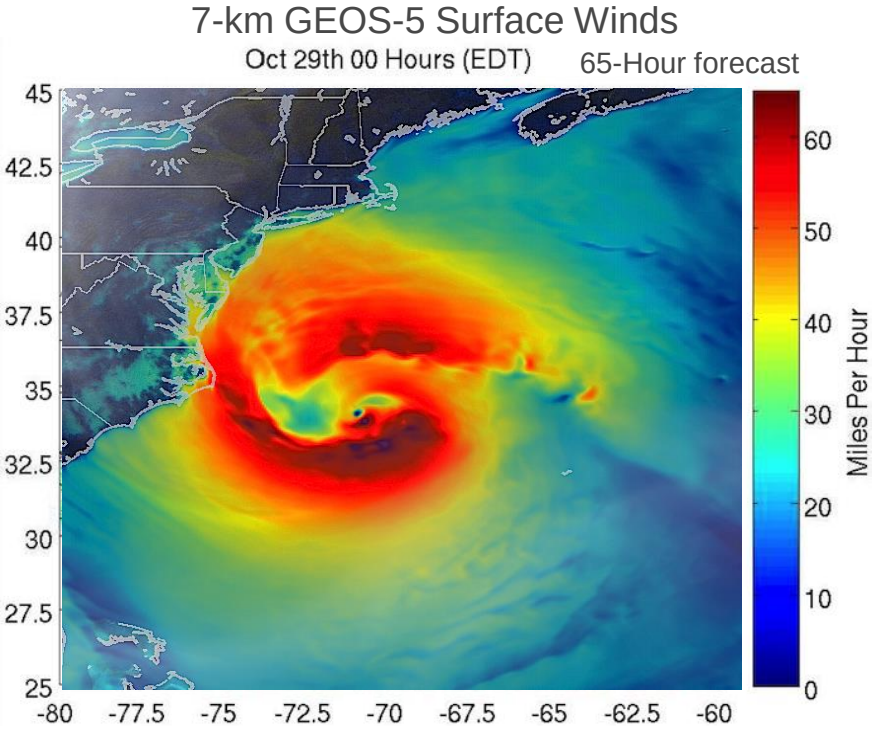
– Particularly from Oct 26 through landfall

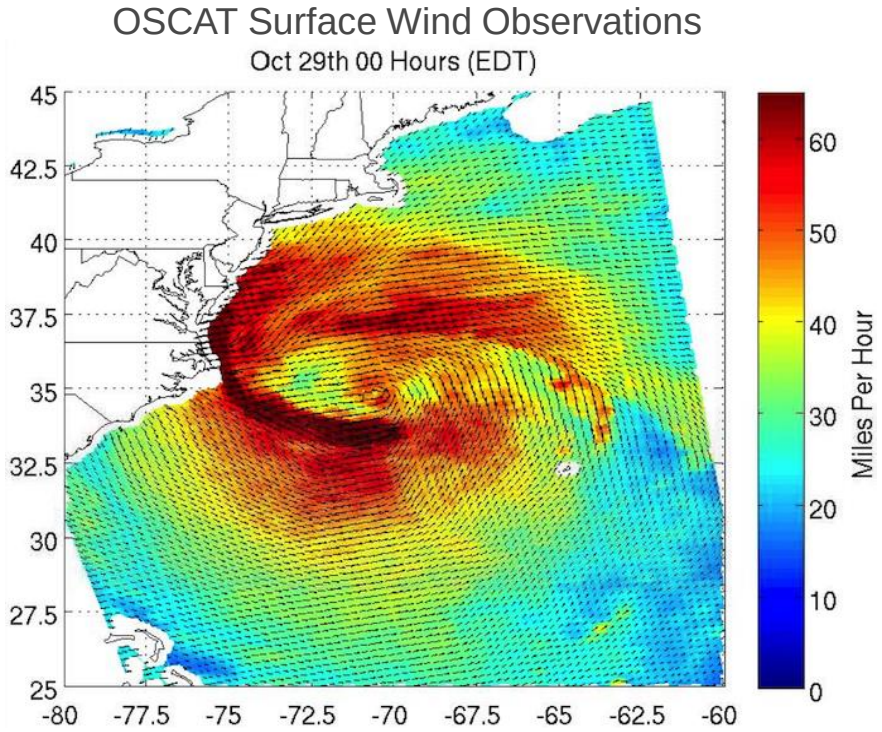
High-resolution improves intensity and structure

– Fine-scale details of surface winds and eyewall

– Fidelity of warm front in the northeast side quadrant



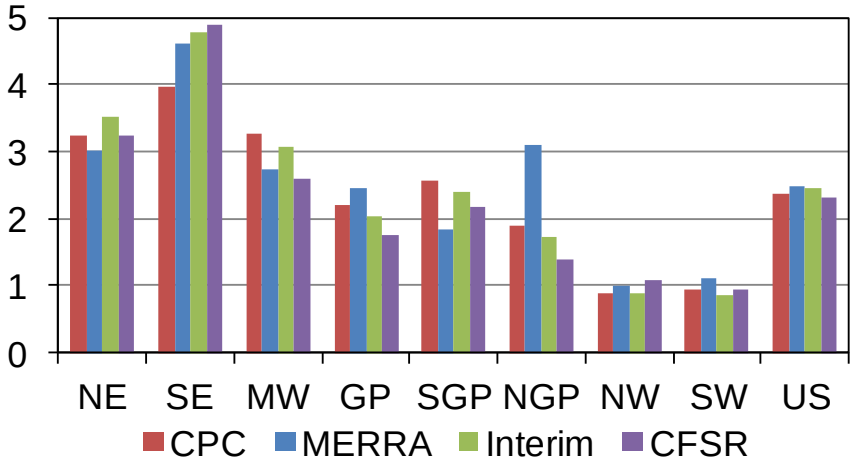


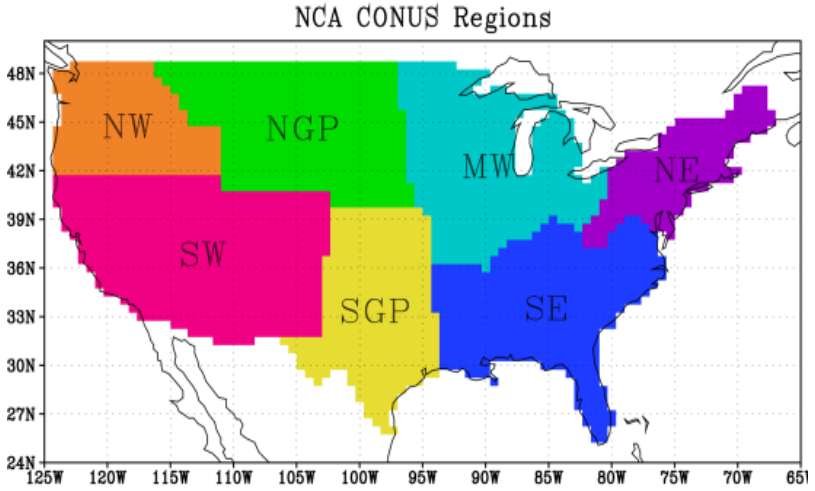


MERRA: Modern-Era Retrospective analysis for Research and Applications
The GEOS-5 atmospheric assimilation analysis of the satellite era: 1979-present

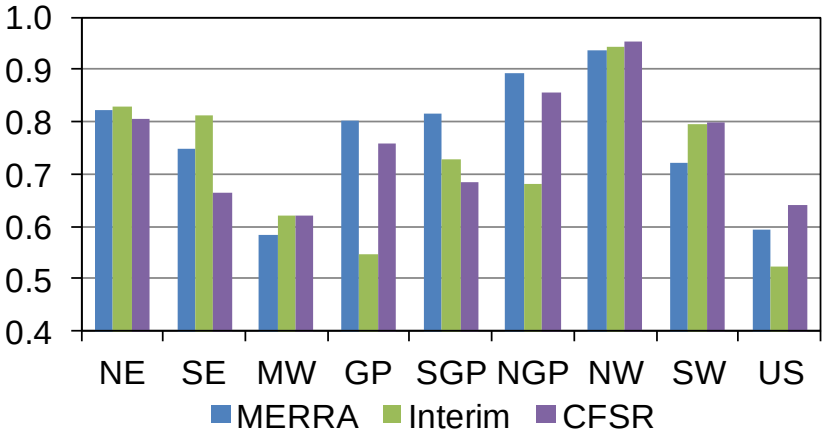
Comparison of regional precipitation for June, July, August (JJA) from CPC gauge observations with reanalyses: NASA's MERRA, ECMWF's ERA-Interim and NCEP's CSFR.

Mean Precipitation (mm/day)

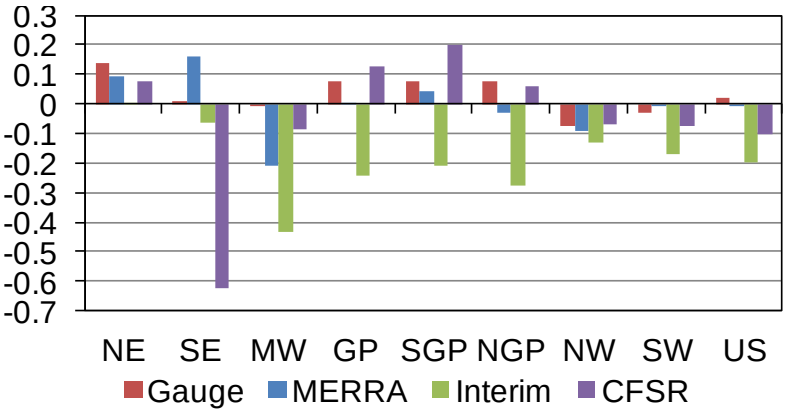




Correlation with CPC obs

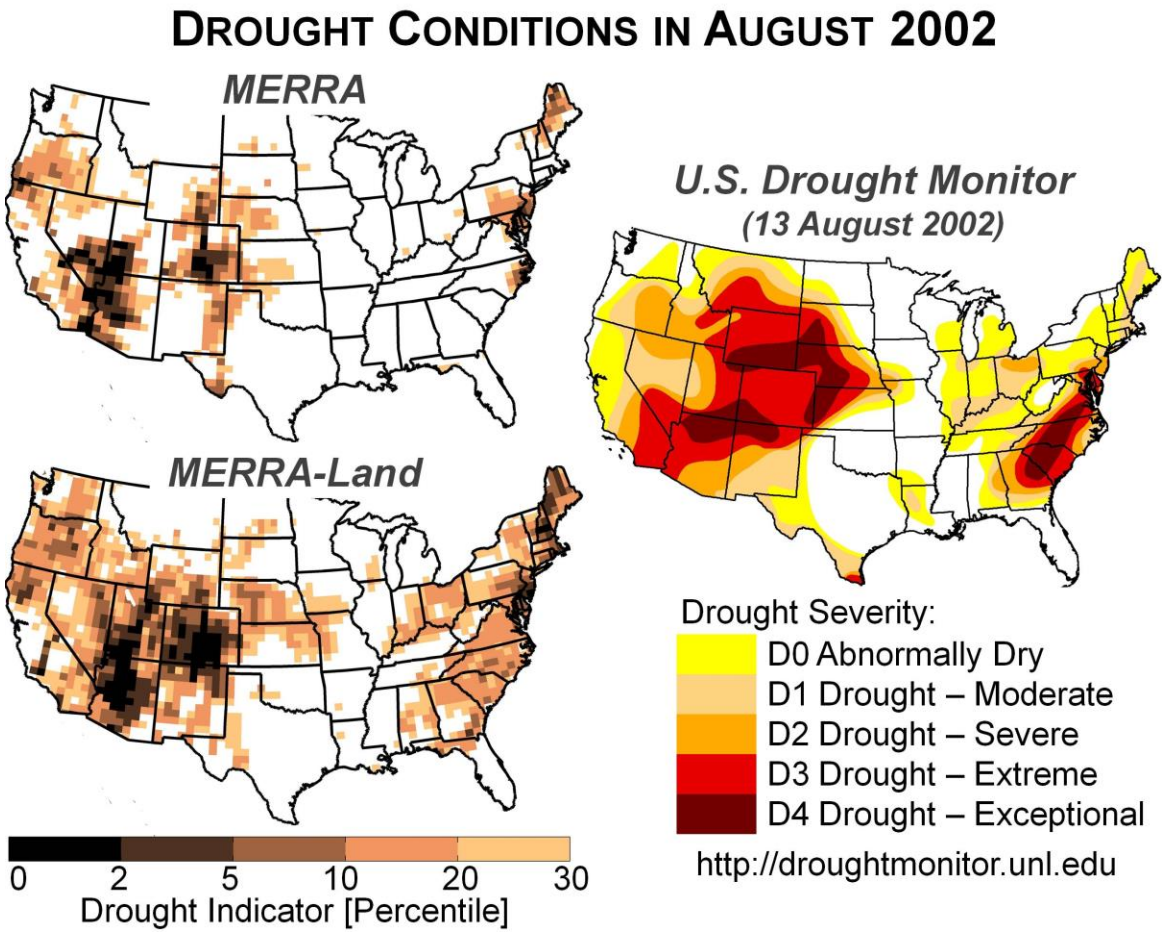


Precipitation Trends (mm/day/decade)



Integrated Earth System Analysis: Other Interactions
Importance of improving precipitation in analyses – MERRA-Land

- Catchment LSM driven offline with MERRA and corrected precipitation
- Global gauge-based precipitation data from CPC used to correct MERRA
- MERRA-Land collection is served at the GES DISC
- Underway: assimilation of soil moisture, snow water equivalent, skin temperature, water storage



http://gmao.gsfc.nasa.gov/merra/merra-land.php

The current GMAO Seasonal Forecast System

GEOS-5 AOGCM

Atmosphere: Initialized from MERRA

AGCM: GEOS-5 AGCM, 1 x 1.25 x L72

Land: taken from MERRA_Land

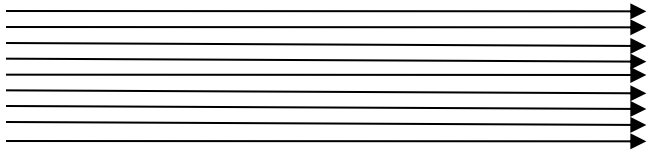
LSM: Catchment

Ocean: Initialized from GEOS-iODAS

OGCM: MOM4, 1/2 x 1/2 x L40, with ¼ equatorial refinement

9 month Coupled Integrations:

11 ensemble members
Initialized beginning of each month and every 5 days
Forecasts delivered to CTB on the 8th of the month



AOGCM: Full coupling.
No flux correction

ODAS: (Conducted in AOGCM with atmosphere constrained by MERRA
Ocean analysis assimilates in situ temperature and salinity profiles, Reynolds SST, sea level anomalies derived from satellite altimeter)
MERRA: Atmospheric analysis for the satellite era using GEOS-5
MERRA_Land: Catchment LSM forced by MERRA surface fluxes with a correction to precipitation

A Multi-Model Ensemble Approach to Seasonal Climate Forecasts

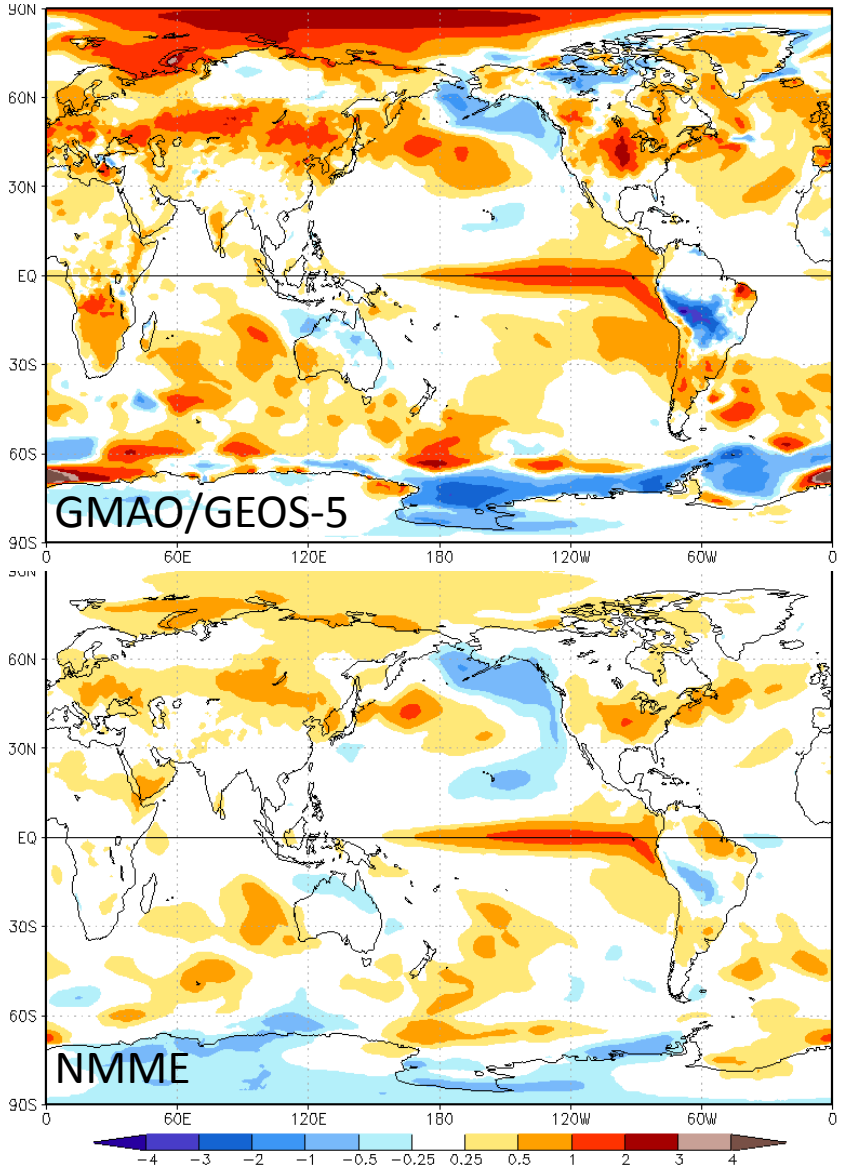
National Multi-Model Ensemble (NMME):

- GMAO contributes
- 7 different models, ~90 ensemble members
- 30 years of hindcasts
- real-time forecasts
- data readily accessible to the greater scientific community

The NMME mean forecast results improve upon those of the individual members.

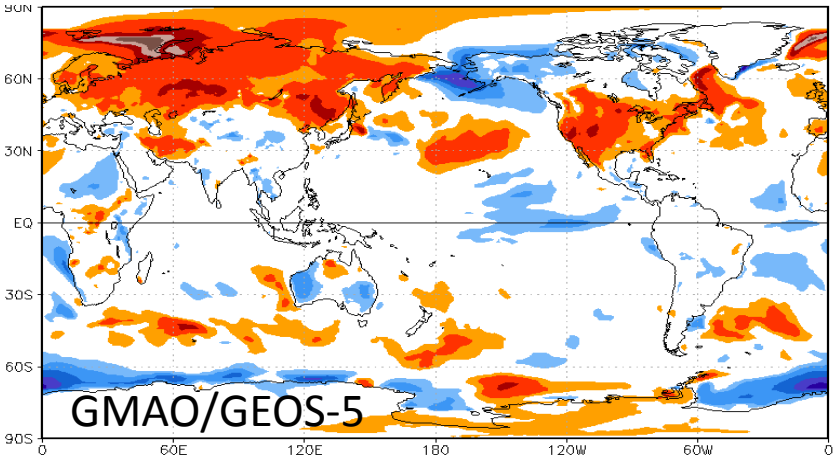
http://www.cpc.ncep.noaa.gov/products/NMME/

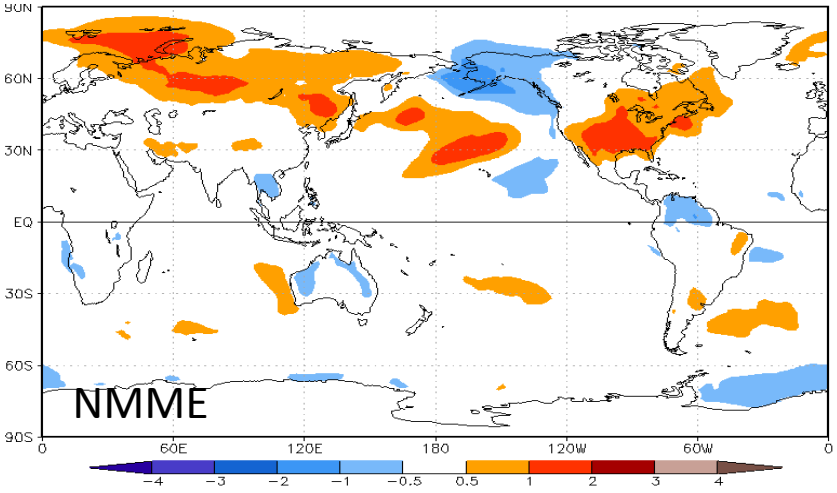
2m Temperature anomaly for JAS 2012 forecast from June initial conditions

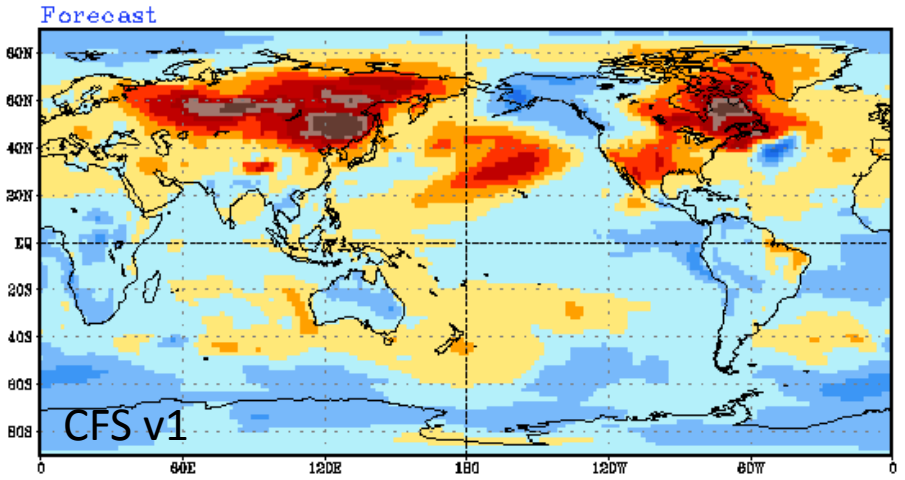


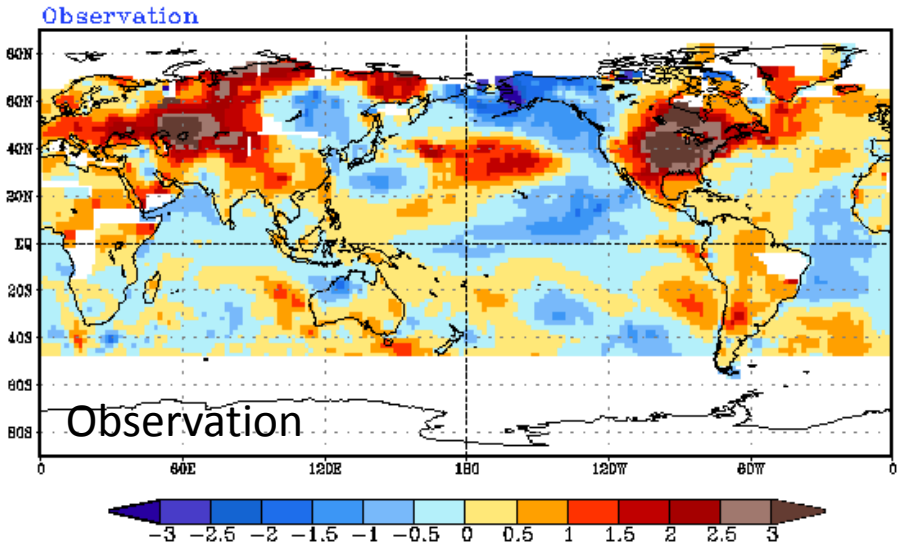
A Multi-Model Ensemble Approach to Seasonal Climate Forecasts

2m Temperature anomaly for MAM 2012 forecast from Feb initial conditions





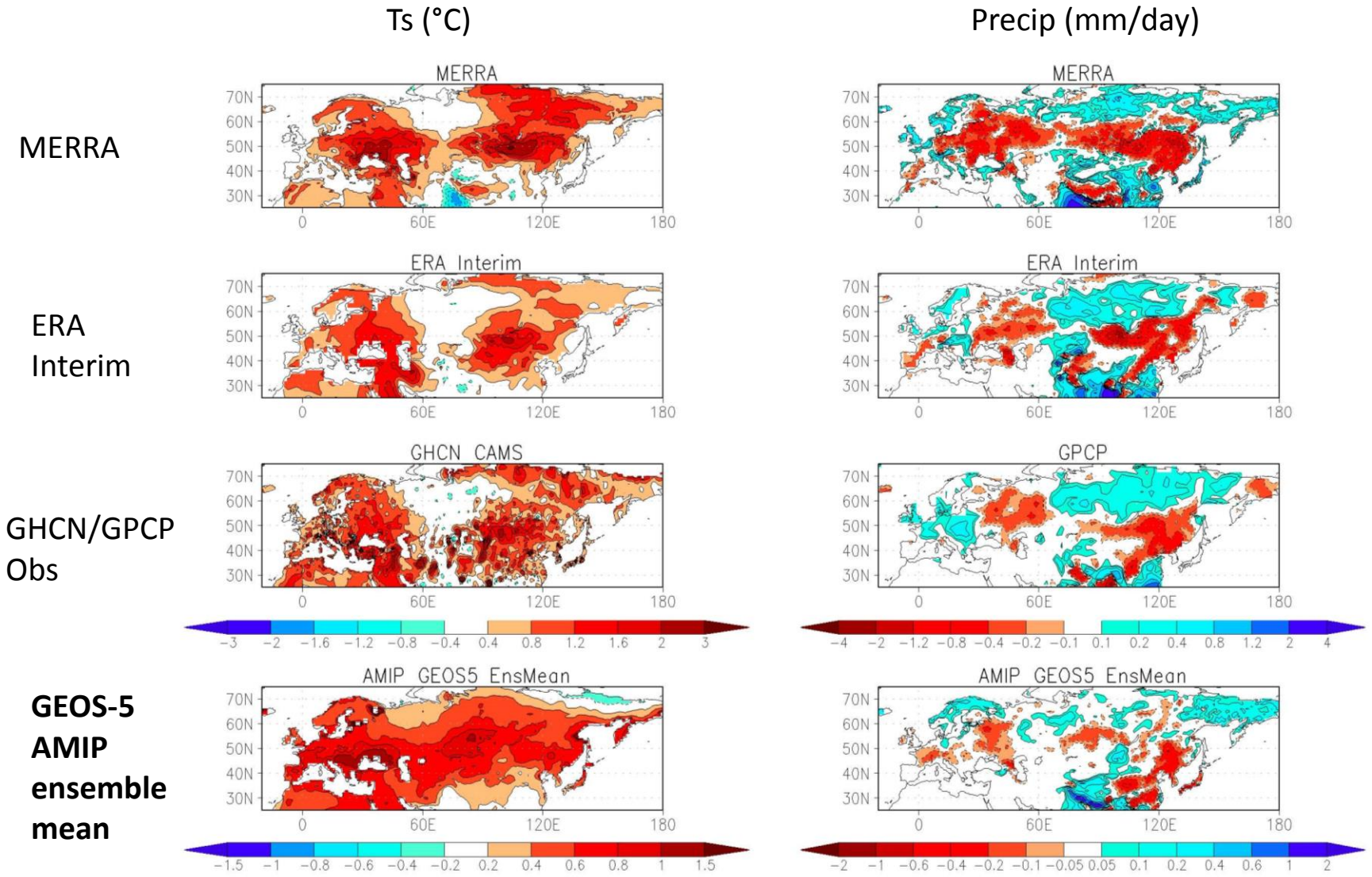




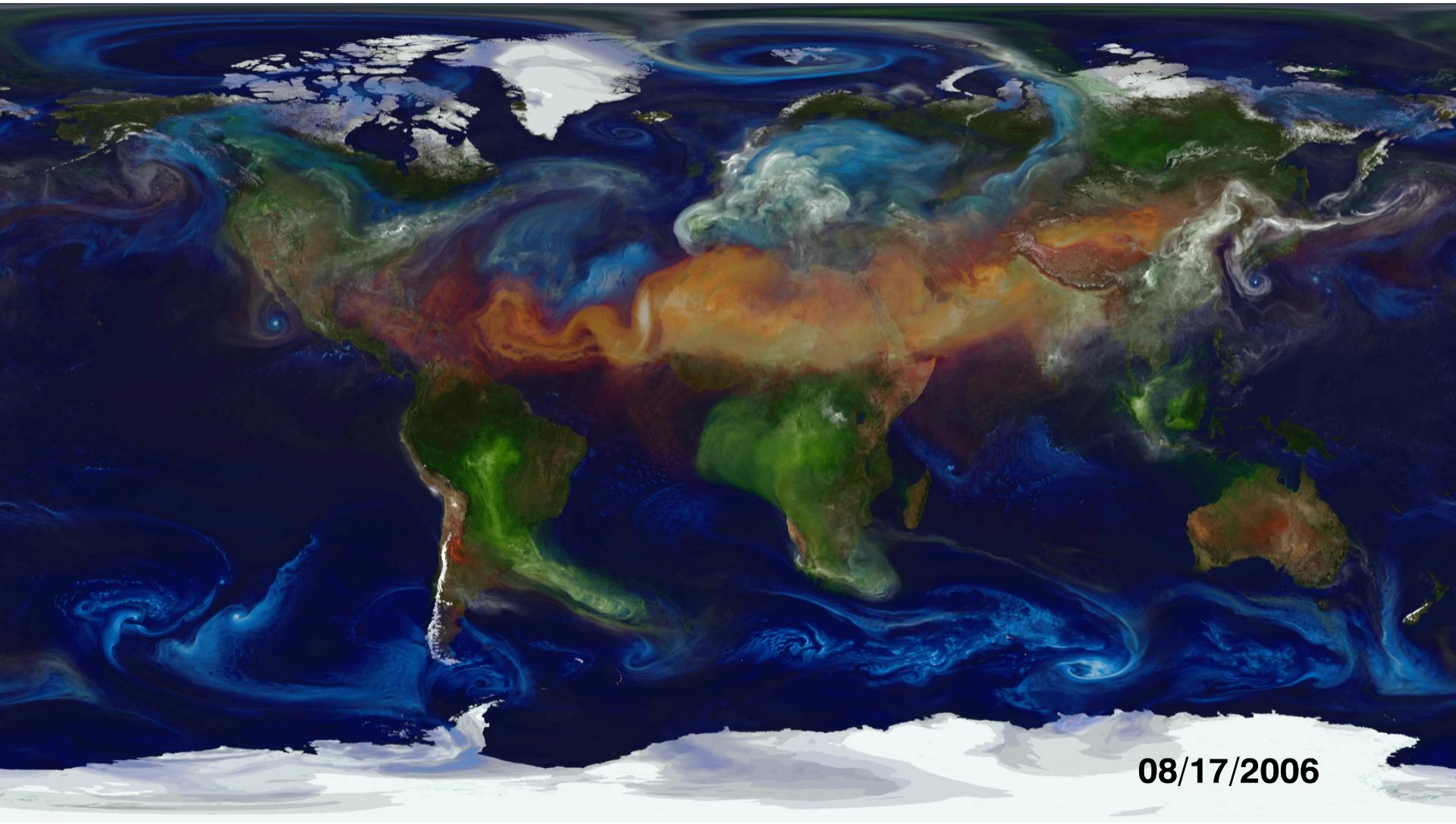
Ensemble average of 40 members from initial conditions of 23Jan2012 to 01Feb2012.

From NOAA/NCEP

Eurasian Climate Changes (1996-2011 minus 1980-1995)



A Dynamic Portrait of Global Aerosols



Red: dust Blue: sea salt Green: black and organic carbon White: sulfate

GMAO Summary

Earth System Science: global models and NASA data

Exploit NASA's high-end computing assets

Timescales:

- weather –to- seasons –to-decades –to- climate

Spatial scales:

- <10km –to– 25km –to– 100km

Complexity of Earth system:

- atmosphere – ocean – land
- aerosols – chemistry – carbon
- extreme events and their impacts
- planning for new missions